

for denitrification during field quantification and the importance of nitrifier denitrification processes are crucial areas of research that need to be understood before management of gaseous N loss can be achieved.

See also: **Fertilizers and Fertilization; Greenhouse Gas Emissions; Microbial Processes:** Kinetics; **Nitrogen in Soils:** Cycle; Nitrification; **Organic Matter:** Principles and Processes; **Organic Residues, Decomposition**

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DESERTIFICATION

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Introduction

Ecosystems in semiarid and arid regions around the world appear to be undergoing various processes of degradation commonly described as ‘desertification.’ According to the United Nations Environmental Program (UNEP), all regions in which the ratio of total annual precipitation to potential evapotranspiration (P/ET) ranges from 0.05 to 0.65 should be considered vulnerable to desertification. Such regions constitute some 40% of the global terrestrial area. They include northern Africa, southwestern Africa, southwestern Asia, central Asia, northwestern India and Pakistan, southwestern USA and Mexico, western South America, and much of Australia, and are home to an estimated sixth of the world’s population.

‘Desertification’ is a single word used to cover a wide variety of interactive phenomena – both natural and anthropogenic – affecting the actual and

potential biological and agricultural productivity of ecosystems in semiarid and arid regions. It is an emotive term, conjuring up the specter of a tide of sand swallowing fertile farmland and pastures. Apparently with this somewhat simplistic image in mind, UNEP sponsored projects in the early 1980s to plant trees along the edge of the Sahara, with the aim of warding off the invading sands. While there are places where the edge of the desert can be seen encroaching on fertile land, the more pressing problem is the deterioration of the land due to human abuse in regions well outside the desert. The latter problem emanates not from the expansion of the desert *per se* but from the centers of population outside the desert, owing to human mismanagement of the land. A vicious cycle has begun in many areas: as the land degrades through misuse, it is worked or grazed ever more intensively, so its degradation is exacerbated; and as the returns from ‘old’ land diminish, ‘new’ land is brought under cultivation or under grazing in marginal or even submarginal areas.

As defined in recent dictionaries, desertification is the process by which an area becomes (or is made to become) desert-like. The word ‘desert’ itself is derived

from the Latin *desertus*, being the past participle of *deserere*, meaning 'to desert,' 'to abandon.' The clear implication is that a desert is an area too barren and desolate to support human life. An area that was not originally desert (e.g., a steppe or savanna) may come to resemble a desert if it loses so much of its usable resources that it can no longer provide adequate subsistence to a given number of humans. This is a very qualitative definition, since not all deserts are the same. An area's resemblance to a desert does not make it a permanent desert if it can recover from its damaged state, and, in any case, the modes of human subsistence and levels of consumption differ greatly from place to place.

In recent decades, the very term 'desertification' has been called into question as being too vague, and the processes it purports to describe too ill-defined. Some critics have even suggested abandoning the term, in favor of what they consider to be a more precisely definable term, namely 'land degradation.' However, 'desertification' has already entered into such common usage that it can no longer be revoked or ignored. It must therefore be clarified and qualified so that its usage is less ambiguous.

'Land degradation' itself is a vague term, since the land may be degraded with respect to one function and not necessarily with respect to another. For example, a tract of land may continue to function hydrologically – to regulate infiltration, runoff generation, and groundwater recharge – even if its vegetative cover is changed artificially from a natural species-diverse community to a monoculture and its other ecologic functions are interrupted. Perhaps better than 'land degradation' is the term 'semiarid ecosystem degradation.' A semiarid ecosystem encompasses the diverse biotic community sharing the domain. Included in this community is the host of plants, animals, and microorganisms that interact with one another through such modes as competition or symbiosis, predation, and parasitism. It also includes the complex physical and chemical factors that condition the lives of those organisms and are in turn influenced by them. Each ecosystem performs a multiplicity of ecologic functions. Included among these are photosynthesis, absorption of atmospheric carbon and its incorporation into biomass and the soil, emission of oxygen, and regulation of temperature and the water cycle, as well as the decomposition of waste products and their transmutation into nutrients for the perpetuation of diverse, interdependent forms of life.

A semiarid ecosystem may be more or less natural, relatively undisturbed by humans, or it may be artificially managed, such as an agroecosystem. An agroecosystem is a part of the landscape that is managed for the economic purpose of agricultural production. The transformation of a natural ecosystem into an

agroecosystem is not necessarily destructive if the latter is managed sustainably and productively, and if it coexists harmoniously alongside natural ecosystems that continue to maintain biodiversity and to perform vital ecologic functions. In too many cases, however, the requirements of sustainability fail, especially where agricultural systems expand progressively at the expense of the remaining, more-or-less natural ecosystems. The appropriation of ever-greater sections of the remaining native habitats, impelled by the increase in population as well as by the deterioration of farmland or rangeland due to overcultivation or overgrazing, decimates those habitats and imperils their ecologic functions. In the initial stages of degradation, the deteriorating productivity of an agroecosystem can be masked by increasing the inputs of fertilizers, pesticides, water, and tillage. Sooner or later, however, if such destructive effects as organic matter loss, erosion, leaching of nutrients, and salination continue, the degradation is likely to reach a point at which its effects are difficult to overcome either ecologically or economically.

Key processes related to desertification include drought, primary production and carrying capacity, soil degradation, and use of water resources. The role of social factors is also important.

The Role of Drought

A typical feature of arid regions is that the mode (the most probable) amount of annual rainfall is generally less than the mean; i.e., there tend to be more years with below-average rainfall than years in which the rainfall is above average, simply because a few unusually rainy years can skew the statistical mean well above realistic expectations for rainfall in most years. The variability in biologically effective rainfall is yet more pronounced, as years with less rain are usually characterized by greater evaporative demand, so the moisture deficit is greater than that indicated by the reduction of rainfall alone. Timing and distribution of rainfall also play crucial roles. Below-average rainfall, if well distributed, may produce adequate crop yields, whereas average or even above-average rainfall may fail to produce adequate yields if the rain occurs in just a few ill-timed storms with long dry periods between them.

In semiarid agricultural regions, 'drought,' like desertification, is a broad, somewhat subjective term that designates years in which cultivation becomes an unproductive activity, crops fail, and the productivity of pastures is significantly diminished. Drought is a constant menace, a fact of life with which rural dwellers in arid regions must cope if they are to survive. The occurrence of drought is a certainty, sooner or later; only its timing, duration, and severity are ever

in doubt. And it is during a drought that ecosystem degradation in the form of denudation and soil erosion occur at an accelerated pace, as people try to survive in a parched habitat by cutting the trees for fuel and browse, and by animals overgrazing the wilted grass. The topsoil, laid bare and pulverized by tillage or the trampling of animals, is then exposed to a greatly increased risk of wind erosion. When the coveted rains recur, they tend to scour the erodible soil.

Any management system that ignores the eventuality of drought and fails to provide for it ahead of time is doomed to fail in the long run. That provision may take the form of grain or feed storage (as in the biblical story of Joseph in Egypt), or of pasture tracts kept in reserve for grazing when the regular pasture is played out, or of the controlled migration of pastoralists to other regions able to accommodate them for the period of the drought.

A much-debated question is whether the frequency, duration, and severity of droughts have been increasing in recent decades. One possibility is that the process of desertification, once begun, produces a feedback effect that is self-exacerbating. Some have hypothesized that the increase in atmospheric dust from denuded and wind-eroded drylands (the so-called dust-bowl effect), as well as from air pollution (as denudation of an area's vegetation is associated with biomass burning, which releases smoke into the air), may have changed the patterns of air mass movement and hence of precipitation. Another hypothesis is that droughts can be worsened by the increased reflectivity of the bared surface to incoming sunlight. That reflectivity, called 'albedo,' may rise from approximately 20% for a well-vegetated area to perhaps 35% or more for an exposed, bright, sandy soil. As a larger proportion of the incoming sunlight is reflected skyward rather than absorbed, the surface becomes cooler than it would be otherwise, and so the air in contact with the surface has less of a tendency to rise and condense its moisture so as to yield rainfall.

An additional effect of denudation is to decrease the interception of rainfall by vegetation and the infiltration rate, while increasing surface runoff, thereby reducing the amount of soil moisture available for evapotranspiration. Crops and grasses, which have shallower roots than trees and in any case transpire less than the natural mixed vegetation of the savanna, transpire even less when deprived of moisture during a drought. The 'biophysical feedback' hypothesis is that such changes may reduce regional precipitation. Lower rainfall leads in turn to more overgrazing and less regrowth of biomass, and to further reduction in reevaporated rain owing to the decline in soil moisture. Thus, the feedback hypothesis offers

its own explanation as to why the drought in the African Sahel, for example, has tended to persist.

Primary Production and Carrying Capacity

The biological productivity of any ecosystem is due to its primary producers (known as autotrophs), which are the green plants growing in it. They alone are able to create living matter from inorganic materials. They do so by combining atmospheric carbon dioxide with soil-derived water, thus converting radiant energy from the sun into chemical energy in the process of photosynthesis. Green plants also respire, which is the reverse of photosynthesis, and in so doing they utilize part of the energy to power their own growth. The net primary production then becomes available for the myriad of heterotrophs, which subsist by consuming (directly or indirectly) the products of photosynthesis. A stable ecosystem is one in which production and consumption, synthesis and decomposition, are in balance over an extended period of time.

When humans enter into an ecosystem and appropriate some of its products for themselves, they do so in competition with other potential consumers. As populations increase, the tendency is to intensify the use of resources by promoting the production of desired goods while suppressing the species that do not serve that end. In the process, the ecosystem's biodiversity and natural productivity are profoundly affected. Especially affected are areas within the semi-arid and arid regions, which, because of the paucity of water and the fragility of the soil (typically deficient in organic matter, structurally unstable, and highly erodible) are most vulnerable and least resilient.

The term 'carrying capacity' has been used to characterize an area's productivity in terms of the number of people or grazing animals it can support per unit area on a sustainable basis. However, the productive yield obtainable from an area depends on how the area is being used. Under the hunter-gatherer mode of subsistence, an area may be able to carry only, for example, 1 person per square kilometer, whereas under shifting cultivation it may carry 10, and under intensive agriculture perhaps 100. The intensive forms of utilization also involve inputs of capital, energy, and materials, such as fertilizers and pesticides, which are brought in from the outside to enhance an area's productivity. As the usable productivity is strongly affected by the supply of water (i.e., by seasonal rainfall), it varies from year to year and from decade to decade, so a long-term average is difficult to determine, especially given the prospect of climate change. It is therefore doubtful if any given area can be assigned an intrinsic and objectively quantifiable carrying

capacity. By whatever measure, however, the capacity of an area to support a given population is clearly diminished by human mismanagement.

Wherever human pressure on the land ceases or is diminished, even a severely eroded soil may recover gradually. However, on the time-scale of years to a few decades, especially if overgrazing and overcultivation continue, soil erosion may become, in effect, irreversible.

Soil Degradation and Rehabilitation

An important criterion of soil degradation is the loss of soil organic matter. Compared with soils in more humid regions, those in warm arid regions tend to be inherently poor in organic matter from the outset, owing to the relatively sparse natural vegetative cover and to the rapid rate of decomposition. The organic matter present is, however, vitally important to soil productivity. Plant residues over the surface protect the soil from the direct impact of raindrops and from deflation by wind, and help to conserve soil moisture by minimizing evaporation. Plant and animal residues that are partially decomposed and that are naturally incorporated into the topsoil help to stabilize its structural aggregates, which in turn enhance infiltrability, reduce water loss by runoff, and enable seed germination and root growth. The organic matter present also contributes to soil fertility by the gradual release of nutrients.

When the natural vegetative cover is removed, and especially when the soil is tilled and/or trampled repeatedly, there follows a rapid process of organic matter decomposition and depletion. Accelerated erosion also removes the layer of topsoil that is richest in organic matter. Consequently, the destabilized soil tends to form a surface crust that further inhibits infiltration. Water losses by both runoff and evaporation increase, and the soil loses an important source of nutrients. These destructive processes can be countered or ameliorated by methods of conservation management, including minimum or zero tillage, maintenance of crop residues, the periodic inclusion of green manures in the crop rotation, and agroforestry.

The destructive processes induced by soil mismanagement, and, in contrast, the constructive processes induced by conservation management, though seemingly local, may have – when practiced on a regional scale – an impact on climate change. Soils subject to accelerated decomposition of organic matter tend to release carbon dioxide and thus contribute to the enhanced greenhouse effect. Conversely, soils that are being revegetated and enriched with organic matter can absorb and sequester quantities of carbon that are extracted from the atmosphere in photosynthesis.

Potentialities and Problems of Irrigation

Where fresh water resources (from riverine or underground sources) are available and can be utilized economically, irrigation can be an effective way to intensify and stabilize production in semiarid or arid regions, and thus to relieve the pressure on extensive areas of rain-fed land that are most vulnerable to degradation. Irrigation is the deliberate supply of water to agricultural crops, designed to permit farming in arid regions and to offset drought in semiarid regions. Even in areas where total seasonal rainfall is adequate on average, it may be poorly distributed during the year and variable from year to year.

Wherever traditional rain-fed farming is a high-risk enterprise owing to scarce or uncertain precipitation, irrigation can help to ensure stable production. It not only raises the yields of specific crops but also prolongs the effective crop-growing period in areas with dry seasons, thus permitting multiple cropping (two, three, or even four crops per year) where only a single crop could be grown otherwise. With the security provided by irrigation, additional inputs needed to intensify production further (pest control, fertilizers, improved varieties, etc.) become economically feasible. Irrigation reduces the risk of these expensive inputs being wasted by crop failure resulting from lack of water. Although irrigated land amounts to only some 17% of the world's total cropland, it contributes well over 30% of the total agricultural production. That vital contribution is most important in arid regions, where the supply of water by rainfall is least, even as the demand for water imposed by the bright sun and the dry air is greatest.

Irrigation, however, is not without its own problems. From its inception in the Fertile Crescent some six or more millennia ago, irrigated agriculture, especially in poorly drained river valleys, has brought about processes of degradation that have threatened its sustainability. The application of water to the land tends to raise the water table, which in turn induces the self-destructive twin scourges of waterlogging and salination.

Some investigators include the degradation of irrigated lands in the category of desertification. Though the processes taking place differ fundamentally from those in rain-fed lands, the damage done to injudiciously irrigated lands is indeed in the category of ecosystem degradation. Processes occurring off-site (upstream as well as downstream of the irrigated area) strongly affect the sustainability of irrigation. For example, denudation of upland watersheds by forest clearing, cultivation, and overgrazing induces erosion and the subsequent silting of reservoirs and canals, thereby reducing the water supply. The

construction of reservoirs often causes the submergence of natural habitats as well as of valuable scenic and cultural sites. Concurrently, the downstream disposal of drainage from irrigated land tends to pollute aquifers, streams, estuaries, and lakes with salts, nutrients, and pesticide residues. Finally, the irrigation system itself (its reservoirs, canals, and fields) may harbor and spread water-borne diseases, thus endangering public health. Thus the very future of irrigated agriculture has been called into question.

Experience shows that irrigation can be sustained, but at a cost. The primary cost is the necessary investment in systems of efficient irrigation (avoiding excessive application of water such as causes water-table rise, waterlogging, and salination), as well as in the timely provision of effective land drainage and the safe disposal of its salt-laden effluent.

Social Factors

Social factors are necessarily involved in both semi-arid ecosystem conservation and its inverse, which is ecosystem degradation. Farmers who do not have tenure to the land are not likely to invest in its conservation or improvement. Neither are communities that lack stable institutional structure likely to establish and maintain essential infrastructure and services that enable, encourage, and coordinate farmers' efforts to implement land improvement and conservation measures. And no effective action at all may be possible in the absence of a proactive governmental policy, including the provision of credit or subsidies, professional guidance and training, as well as the preparation and implementation of national and regional drought contingency plans for both farmers and herders. The conservation of soil, water, and biotic resources is a collective societal concern, and an inter-generational one, not merely a private concern of the people utilizing the land directly at any particular time.

Finally, there looms the most difficult, yet inescapable, problem of population numbers. No system of management, however efficient it may be, can be sustained if the population continues to grow without limit. A crucial aspect of population control is the empowerment of women, through education and equal rights, as full participants in the management of their societies' physical, biological, and human resources. The issue is extremely sensitive inasmuch as it carries cultural and traditional, as well as social and economic, implications.

Monitoring Desertification

The techniques of remote sensing have made possible the monitoring of changes to ecosystems on a regional scale. Studies based on remote sensing of the African

Sahel have shown that, contrary to many alarmist reportings, there has been no progressive change of the Saharan desert boundary. Rather, there has been a back-and-forth shifting of vegetative density during alternating spells (sometimes lasting several years) of below-average and of above-average rainfall. In principle, however, statistical criteria designed to test the probability levels of differences (between sites or between successive measurements on the same site) should not be used to 'prove' the opposite, namely that there are no differences. Measurements made at various times on large areas may obscure subtle local changes that could have taken place on a smaller scale.

One of the main indexes in use at present is the so-called normalized difference vegetation index (NDVI). It is obtained from the ratio between the red and near-red infrared reflectance bands, obtained from high-resolution radiometer data generated by the polar-orbiting satellite of the US National Oceanic and Atmospheric Administration (NOAA). In arid and semiarid regions, NDVI evidently correlates with the density of the vegetative cover and its biomass, as well as with its 'leaf area index' (LAI) and its photosynthetic activity. Care is needed, however, in applying NDVI to the assessment of net primary production, since the measurement of NDVI is oblivious to the amount of vegetation harvested by humans and by their animals prior to the time of the measurement.

Taken to be a general indicator of the 'greenness' of an area, NDVI has also been conjectured to correlate with biological productivity, but that correlation may not necessarily hold. In principle, the amount of vegetation present per unit area should depend on the amount produced *in situ* minus the amount removed from it. Therefore, the relation between an area's productivity and its vegetative biomass at any time must depend on whether the vegetation has been or is being 'harvested' (grazed by livestock or cut and carried away by humans). An area could be quite productive, yet relatively bare, if it had been harvested just prior to the NDVI measurement. Even if there is no discernible change in the density of an area's overall vegetative cover, there might well be a considerable change in the composition of the vegetation (i.e., its biodiversity, ecologic function, and feed value). For example, an overgrazed area may exhibit a proliferation of less nutritious plants at the same time that it loses the most palatable species of grasses and legumes that had contributed to the area's original carrying capacity.

Clearly, the most decisive factor affecting the overall density of vegetative cover in an arid region is the fluctuation of rainfall amounts. Taking the African Sahel as an example once again, we see that the annual precipitation has fluctuated widely over the decades. The amounts (as seen in [Figure 1](#)) for the last

three decades of the twentieth century appear to be generally lower than those in the preceding decades. Although an analysis based on any particular short period may be misleading, the question does arise as to the possible effects of global climate change.

The Role of Climate Change

Ecosystems in arid and semiarid regions are likely to be increasingly influenced by global climate change. Emissions of radiatively active gases and aerosols due to human activity are altering the Earth's radiation balance and hence the temperature of the lower atmosphere. One of the manifestations of the change may be an increase in climate instability. In a warmer world, climatic phenomena are likely to intensify. Thus, episodes or seasons of anomalously wet conditions (violent rainstorms of great erosive power) may alternate with severe droughts, in an irregular and unpredictable pattern.

A more unstable climatic regime will make it harder to devise and more expensive to implement optimal land use and agricultural production practices, including drought-contingency provisions. Failure to prepare for such contingencies may exacerbate the consequences of extreme events such as floods

and droughts, to the effect of worsening land degradation and periods of severe food shortages. Especially vulnerable is the continent of Africa, where the issues of greatest concern pertain to human health and food security, water resources, natural ecosystems and biodiversity, and, not least, land degradation or desertification (Table 1).

Climate change appears likely to cause further semiarid ecosystem degradation through alteration of spatial and temporal patterns in temperature, rainfall, solar insolation, winds, and humidity. Analyses based on global and regional climate models suggest that droughts may become more frequent, severe, and prolonged. It is still impossible, however, to ascribe exact probabilities to any of the various climate change scenarios, owing to uncertainties regarding future emissions of the radiatively active trace gases and tropospheric aerosols, and the potential responses of the climate system to those changes.

The question is sometimes posed: is it human exploitation of the land or is it overall climate change that constitutes the predominant cause of desertification? The answer is that the two sets of factors or processes interact and may well have become mutually reinforcing. Ultimately, both are impelled by human intervention and therefore can only be redressed by coordinated actions at the local, regional, and global levels.

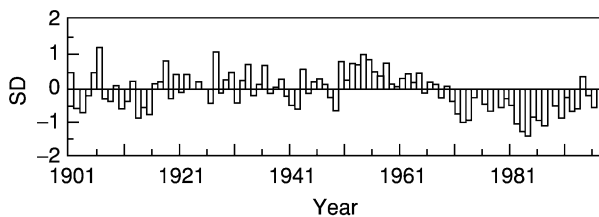


Figure 1 Rainfall fluctuations in the African Sahel during the period 1901–1998, expressed as a regionally averaged standard deviation, SD (departure from the long-term mean divided by the standard deviation). Reproduced from Densanker P and Magadza C (2001). *Africa in climate change 2001: impacts, adaptation and vulnerability*. In: McCarthy JJ, Canzania OF, Leary NA, Dokker DD, and White KS (eds) *International Panel of Climate Change*.

Overview

The pressures generated by growing populations, intensified land use, and overall environmental change are evidently causing a progressive degradation of natural and managed ecosystems, especially in arid and semiarid regions. To define and quantify the nature, degree, and extent of the degradation, national and international agencies are working to implement consistent monitoring programs. These consist not only of remote sensing from above but also of ground-based observations.

Table 1 Sectors vulnerable to climate change in Africa

Sector	Projected impacts
Water resources	Dominant impact is predicted to be a reduction in soil moisture in the subhumid zones and a reduction in runoff
Food security	There is wide consensus that climate change, through increased extremes, will worsen food security in Africa
Natural resources and biodiversity	Climate change is projected to exacerbate risks to already threatened plant and animal species, and fuelwood
Human health	Vector-borne and water-borne diseases are likely to increase, especially in areas with inadequate health infrastructure
Desertification	Changes in rainfall, increased evaporation, and intensified land use may put additional stresses on arid, semiarid, and dry subhumid ecosystems

Reproduced from Densanker P and Magadza C (2001) *Africa in climate change 2001: impacts, adaptation and vulnerability*. In: McCarthy JJ, Canzania OF, Leary NA, Dokker DD, and White KS (eds) *International Panel of Climate Change*.

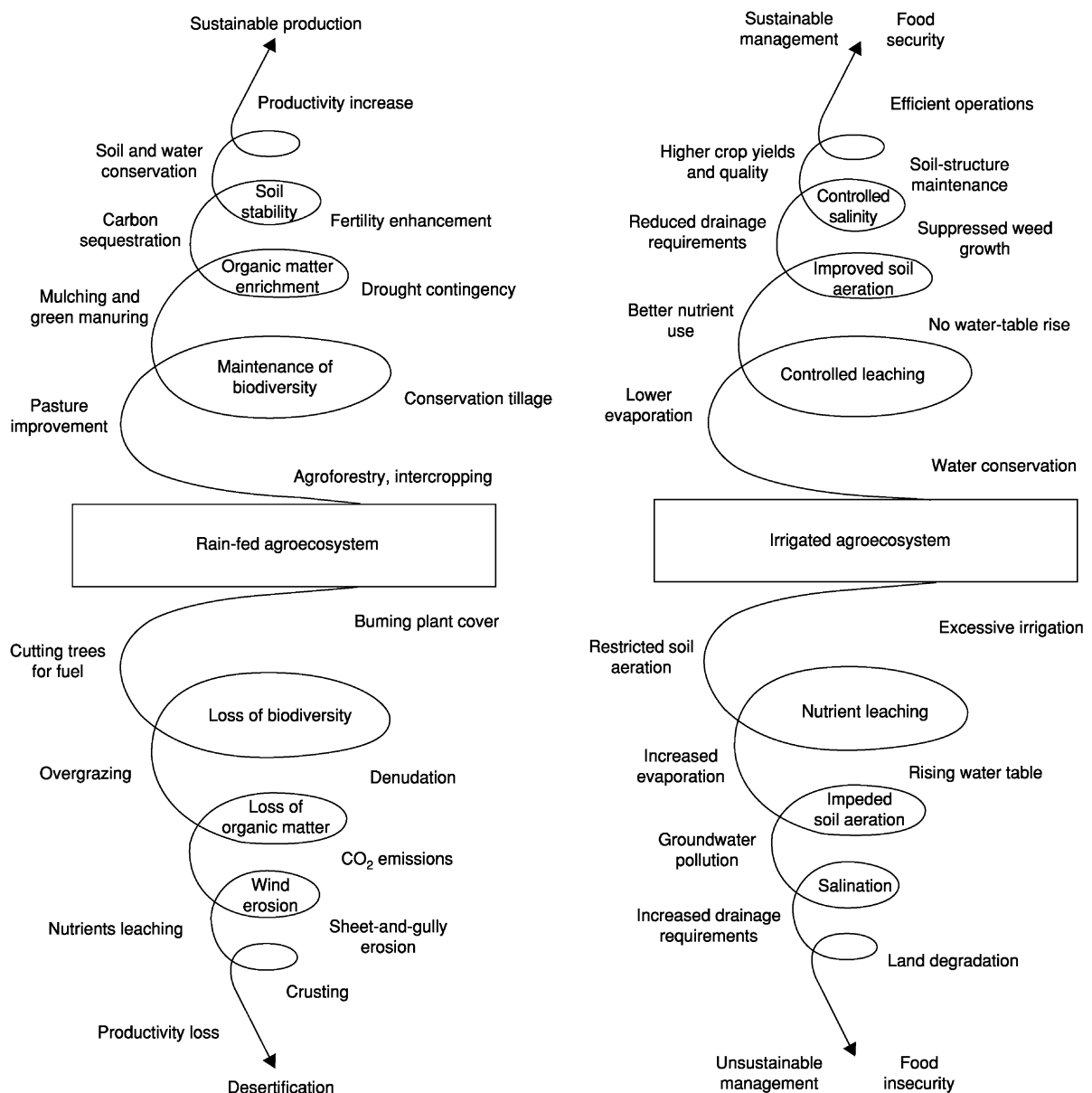


Figure 2 Upward and downward spirals of sustainable versus unsustainable patterns of management in rain-fed and irrigated agriculture in arid regions. Reproduced with permission from Hillel D and Rosenzweig C (2002) Desertification in relation to climate variability and change. *Advances in Agronomy* 77: 1–38.

To redress or rehabilitate degraded ecosystems, vulnerable countries are beginning to institute appropriate policies and programs. These include keeping reserve areas to protect biodiversity, avoiding overgrazing on managed lands, reseedling of pastures, implementing soil and water conservation measures, and – in the social arena – land tenure, family planning, and contingencies for droughts. Determining the availability of fresh water resources (surface water, renewable groundwater, and, in some cases, nonrenewable groundwater as well) and planning their careful utilization are important components of such programs. Inappropriate patterns of management

may lead to a downward spiral of ecosystem degradation, whereas appropriate measures of conservation and sustainable use hold the promise of sustainable development in the context of both rain-fed and irrigated agriculture (Figure 2).

See also: **Degradation; Erosion:** Water-Induced; Wind-Induced

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DIFFUSION

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Introduction

In soil science the diffusion of gases and solutes needs to be understood. A gas in a closed vessel distributes itself such that its pressure is the same at all points. If there is a mixture of gases, each exerts its own 'partial pressure' and distributes itself such that its partial pressure is the same throughout the vessel. If you change the partial pressure of one gas in any part of the vessel there will be a gradient in its partial pressure, and the resulting flow of that gas within the other gases will tend to equalize its partial pressure throughout the volume. A solute in a solution behaves in several ways like a gas in a closed vessel. It has a chemical potential, which depends on its concentration and is conceptually related to the partial pressure of a gas through the thermodynamic concept of free energy. The solute distributes itself so that its concentration and chemical potential are the same throughout the solution, as a gas does with its partial pressure in a closed vessel. Changing the concentration in any part of the solution leads to a gradient in chemical potential which causes a flow of solute that tends to equalize the concentration. You

can readily watch this happening by placing a crystal of potassium permanganate at the bottom of a beaker of water. There is a gradient of chemical potential between the solution adjacent to the crystal and the rest of the water, and the rich purple color of the permanganate gradually spreads out into the water. This process, which is essentially the same for gases and solutes, is diffusion, which involves gases that diffuse in the soil atmosphere, that is, within other gases, and solutes that diffuse in the soil solution, often interacting with soil solids. Although diffusion in solution is caused in principle by gradients in chemical potential, the topic is usually treated in terms of the concentration.

How Diffusion Occurs

Diffusion occurs because of Brownian motion, the random movement of ions or molecules in a state of thermal motion. Although the molecules move randomly, the probability is that gas molecules will move from high-pressure to low-pressure zones, and solute molecules from zones of high concentration to zones of lower concentration in a solution. Because gradients in partial pressure and concentration are gradually lessened by diffusion but never eliminated, partial pressures and concentrations of solute become uniform only at infinite time (although in practice many diffusive flows become too small to measure after a relatively short time). This is why many diffusion